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EFFECT OF CORROSION INHIBITORS ON CONDUCTIVITY OF AVIATION TURBINE FUEL

Richard C. Striebich, 1Lt, USAF

Fuels Branch
Fuels and Lubrication Division

March 1986

Final Report for Period December 1982 - June 1984

CT

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is the result of an investigation to determine the effects of corrosion inhibitors on the conductivity of aviation turbine fuel. Fourteen inhibitors were examined for their effects on JP-4 (and other fuels) with three different anti-static additives. Three of the fourteen corrosion inhibitors significantly decreased the conductivity of the fuel with anti-static additive. Of these three inhibitors, one showed a decrease in conductivity of more than 40% when blended with STADIS 450 anti-static additive. This study resulted in a change of the Qualified Products List (QPL) for corrosion inhibitors. Keywords

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JP-4 Jet Fuel	Compatibility

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FOREWORD

This technical report describes an experimental study of the effects of corrosion inhibitors on the conductivity of aviation turbine fuel. Part of the work reported here was performed in-house under Work Unit 30480591, "Fuel Evaluation and Development" which is administered by the Fuels Branch (AFWAL/POSF), Fuels and Lubrication Division (POS), Air Force Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. Other parts of this work were performed by Monsanto Research Corporation under Work Unit 30480515, "Properties of Aircraft Fuels and Related Materials", administered by the Fuels Branch (Mr. Timothy L. Dues). The in-house work described in this report was performed by Lt Richard C. Striebich from November 1982 to February 1984. The principal investigator for the extensive work done at Monsanto was Mr Donald Duvall.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
bbl	barrel
dc	direct current
pS/m	pico Siemens/meter
ppm	parts per million
QPL	Qualified Products List

SECTION I

INTRODUCTION

Distillate fuels may become charged electrostatically during such operations as refueling, filtering or mixing due to the separation of positive and negative ions in the fuel. This charge separation could occur when identically charged particles adhere to the surface of a tank, filter or other part of a fuel system and ions of the opposite charge flow with the fuel. If the fuel's conductivity is low, the fuel is not able to readily transport this charge to other surfaces in the fuel system. If, for example, an aircraft is being refueled, low conductivity fuel may build up a significant static charge in the aircraft fuel tank. When the potential exceeds a critical value for the system, a discharge may occur in the vapor space. Obviously, this kind of occurrence would have disasterous consequences if a flammable fuel/air mixture was present. The Air Force and Navy have reported numerous incidents in the last decade solely related to electrostatic discharge. In the past few years, more than 50 incidents have been reported in the Air Force's A-10 aircraft probably due to the blue foam. This figure does not take into account incidents related to electrostatic discharge because of fuel flowing through fire suppressive blue foam.

The Air Force has been using anti-static or static dissipator additives for a number of years. The conductivity of JP-4 aviation fuel without this additive would typically range from 1 - 10 pS/m (pico-Siemens per meter). Aviation turbine fuel (JP-4) specification MIL-T-5624L (Reference 1) calls for a fuel conductivity between 200 and 600 pS/m. This level of conductivity should be sufficient to deter any type of electrostatic discharge from a fuel through its vapor space. Refineries, in their quest for reduced costs, add static dissipator additives in as low a concentration as possible so that the 200-600 pS/m specification is met. For example, if static dissipator additive were to interact with other additives like corrosion inhibitors, to decrease conductivity, then additional static dissipator additive would have to be added to the fuel to ensure proper conductivity. Through this study the Air Force hopes to curtail the use of those corrosion inhibitors on the Qualified Products List (QPL) which decrease conductive properties. Refineries would then need less anti-static additive in their fuels in order to meet conductivity specifications. Resultant fuels would be less expensive due to decreased additive concentration, but more importantly, fuels would not be expected to show any instability because of higher concentrations of high molecular weight additives.

Some corrosion inhibitors have been noted to decrease conductivity by as much as 40% in the field; however, little documentation has been provided by laborato experimentation to validate this observation. Thus, this report describes experiments carried out by the Fuels Branch, Aero Propulsion Laboratory, Wright-Patterson AFB, to investigate the effect of corrosion inhibitors on the conductivity of aviation turbine fuel with anti-static additives.

SECTION II

CURRENT RESEARCH

1. EXPERIMENTAL TEST PLAN

a. Overview

The investigations described herein were designed to test the compatibility of corrosion inhibitors with aviation turbine fuels, as specified in MIL-I-25017D (Reference 2). In the compatibility section of this specification, paragraph 4.6.2.1 calls for compatibility test to be run by adding corrosion inhibitors to JP-4 in their maximum allowable concentrations. At the end of a 24-hour equilibration period, a visual inspection of the samples should show no signs of cloudiness or precipitation.

Paragraph 4.6.2.2 of MIL-I-25017D describes the requirements for compatibility of the corrosion inhibitors with static dissipator additives. The manner in which conductivity effects may be tested is very explicitly stated in this paragraph:

> Grade JP-4 fuel (MIL-T-5624), filtered through clay as described in Appendix A.4 of ASTM D2550 (Reference 3), shall be blended with each static dissipator additive approved in MIL-T-5624 to provide test fuels having a conductivity of 400 picosiemens per meter (pS/m) +/-100 pS/m. After a 24-hour period to insure that equilibrium of fuel conductivity has been established, the inhibitor under test shall be added and mixed. At the end of another 24-hour period, no more than 40% change in the electrical conductivity of the fuel shall have occurred as a result of the test inhibitor. The fuel electrical conductivity shall be measured using either ASTM D2624 (Reference 4) or D3114 (Reference 5) test methods... No significant change in temperature should be allowed during the test.

Thus, the purpose of the present study is to determine which, if any of the 14 corrosion inhibitors on the Qualified Products List (QPL) (Reference 6), will cause a significant change in the conductivity of a JP-4 fuel with anti-static additive.

The entire experiment was divided into three phases. In Phase I, a baseline fuel was prepared by blending ASA-3 anti-static additive into a double clay-treated JP-4 to yield a fuel with a conductivity of approximately 400 pS/m. One gallon epoxy-lined cans were used to store this base fuel blended with each of 14 corrosion inhibitors at their maximum allowable concentrations. Each sample was shaken on a small paint-can shaker and then allowed to equilibrate for 24 hours. The electrical conductivity of each fuel sample was measured by both ASTM D3114 and D2624. If an increase or decrease of more than 40% was found due to the corrosion inhibitor (relative to the conductivity of the baseline fuel), the concentration was decreased in 1 lb/1000 bbl increments from the maximum allowable concentration by dilution with the baseline fuel. For example, if a sample showed a conductivity decrease of 55% with 8 lbs/1000 bbls of corrosion inhibitor "A", the solution would be diluted with baseline fuel (JP-4 plus ASA-3) to 7 lbs/1000 bbls of inhibitor "A". If this solution still produced a conductivity change greater than 40% from the base fuel, a concentration of 6 lbs/1000 bbls was tested. This procedure was carried out until the minimum effective concentration was reached or a change in conductivity of less than 40% was noted.

After testing all 14 corrosion inhibitors in the JP-4 plus ASA-3 baseline fuel, Phase II of the testing began. Phase II was similar to Phase I except that two different anti-static additives were substituted for ASA-3 in the JP-4, i.e., STADIS 450 and TOLAD 511 anti-static additives. As in Phase I, the corrosion inhibitors were added at their maximum allowable concentrations and then diluted until a change of less than 40% was observed when compared to the baseline fuel.

The objective of Phase III testing was to re-examine those corrosion inhibitors displaying "borderline" or "failing" compatibility; i.e., to retest those corrosion inhibitors which showed considerable conductivity change for any of their allowable concentrations. In addition to the petroleum JP-4 used in Phases I and II, five other fuel types were evaluated. Both ASA-3 and STADIS 450 (the only two Air Force-approved anti-static additives) were used and the procedure was much the same as that described in Phase I or II. The results of Phases I through III indicated which corrosion inhibitors produce an undesirable change in the conductivity of various aviation fuels.

b. Equipment and Procedures

The equipment used for measuring conductivity is specified in ASTM D3114 and D2624. Briefly, in ASTM D3114 a sample of fuel is contacted with a conductivity cell which is then connected in series with a dc voltage source and ammeter. The conductivity is calculated by Ohm's law from the cell characteristics, the voltage across the cell, and the almost instantaneous peak current reading. Conductivity units are then expressed in pS/m (Reference 5). The method is very similar for ASTM D2624 except that the meter used is a portable rather than a laboratory device. The conductivity reading is directly displayed in either a digital readout or through an analog meter (Reference 4).

The apparatus used for clay-filtering is shown in Figure 1. This single pass, double stage rig was designed for a throughput of approximately five gallons per minute.

There were several procedural precautions which had to be taken to ensure consistent conductivity readings. First, because of the viscosities of the corrosion inhibitors and static dissipator additives, additions to fuels were made on a weight basis rather than by volume. Additives were weighed into a small glass boat and added to the fuel by washing the additive into the sample container with 1000 mls or more of fuel. The temperatures of the samples were recorded while measuring conductivity. Ambient temperatures however, did not vary significantly throughout the experiments.

Sample containers were specially chosen and prepared with a great deal of care. Hayes and Conley (Reference 9) report that different sample containers have varying effects on the conductivity of fuel samples with static dissipator additive. Unlined tin cans and amber and clear glass bottles all decreased conductivity with time. Also, unknown synergistic effects resulted in abnormally high conductivity readings for fuel stored in polyethylene bottles. "Deactivated" one gallon epoxy-lined cans were the only containers which would keep conductivity readings reasonably consistent. Deactivation consisted of rinsing the container with the baseline fuel to be tested in order to "use up" active sites where the additive might otherwise tend to plate out. Without deactivation, conductivity would decrease over time. Consequently, the deactivation procedure was followed for every sample container used in this experiment.

c. Fuels and Additives

The fuel used in the first two phases was a specification grade, petroleum JP-4 which was double clay-filtered to remove any additives already in the fuel. The fuel, contained in an inert, epoxy-lined 55 gallon drum, was blended to 0.571

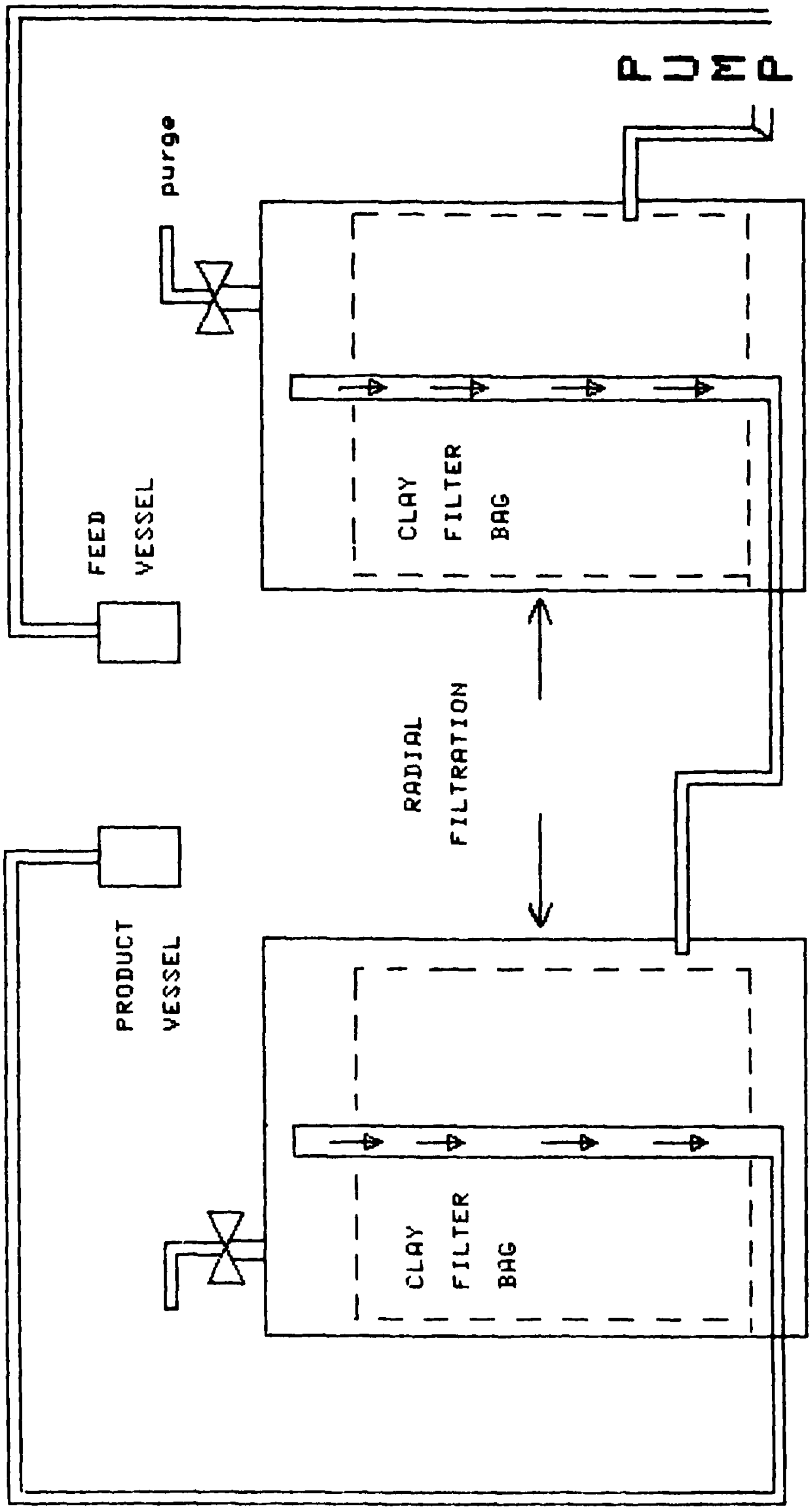


Figure 1. Clay-Filtering Apparatus

ppm ASA-3* static dissipator additive for Phase I testing. This blending produced JP-4 with an electrical conductivity equal to 400 +/-10 pS/m. The same lot of JP-4 fuel was used for Phase II research. In this experiment, one drum of clay-treated fuel was blended with STADIS 450** anti-static additive and another drum with TOLAD 511***. Product descriptions for these two additives may be found in References 7 and 8.

Phase III experiments were conducted for six different fuel types with ASA-3 and STADIS 450 anti-static additives. TOLAD 511 was not used because it is a candidate anti-static additive which has not as yet been approved for Air Force use. A description of the fuels and amounts of static dissipator additives for Phases I - III can be found in Table 1.

The corrosion inhibitors used in this study was specified under the QPL (Reference 6) for fuel-soluble corrosion inhibitors. At the start of this study, there were 14 corrosion inhibitors on the QPL; these additives, along with their minimum effective and maximum allowable concentrations are listed in Table 2.

Air Force usage rates differ for each of these inhibitors. Figures 2 and 3 demonstrate the relative frequency of use of corrosion inhibitors reported to the Air Force in 1977 and 1984.

2. DATA

The data for Phases I, II, and III are provided in Appendices A, B, and C, respectively.

*Shell Oil Company

**E. I. Du Pont De Nemours and Co.

***Tetrolite Division, Petrolite Corp.

TABLE 1. FUEL SAMPLE DESCRIPTION: PHASES I THRU III

Code	Sample Description	ASA-3 Added (ppm)	STADIS-450 Added (ppm)	TOLAD 511 Added (ppm)	Phase
POSF-0708	Petroleum JP-4	0.57	-	-	I
POSF-0708	Petroleum JP-4	-	0.56	-	II
POSF-0708	Petroleum JP-4	-	-	2.11	II
POSF-0708	Petroleum JP-4	1.13	-	-	III
POSF-0708	Petroleum JP-4	-	1.3	-	III
POSF-0113	Shale-Derived JP-4	0.85	-	-	III
POSF-0883	Petroleum JET A (commercial aviation fuel)	1.4	-	-	III
POSF-0883	Petroleum JET A	-	1.6	-	III
POSF-1329	Petroleum JP-8	1.4	-	-	III
POSF-1329	Petroleum JP-8	-	1.5	-	III
POSF-1330	Petroleum JP-4	1.0	-	-	III
POSF-1333	70% iso-octane, 30% toluene mix	1.3	-	-	III
POSF-1333	70% iso-octane, 30% toluene	-	0.56	-	III

TABLE 2. MIL-I-25017 INHIBITOR SAMPLES

INHIBITOR I.D.	CONCENTRATION, lbs/1000 Bbl MIN. EFF. CONC.	MAX. ALLOW. CONC.
APOLLO PRI-19	3	8
ARCO 4410	3	8
DCI-4A	3	8
DCI-6A	3	8
HITEC E-515	7.5	16
HITEC E-580	3	8
LUBRIZOL 541	3	6
MOBILAD F-800	3	8
NALCO 5403	3	8
NALCO 5405	3	8
P 3305*	4.5	12
TOLAD 245	7.5	12
TOLAD 249	3	8
UNICOR J	3	8

*was Emery

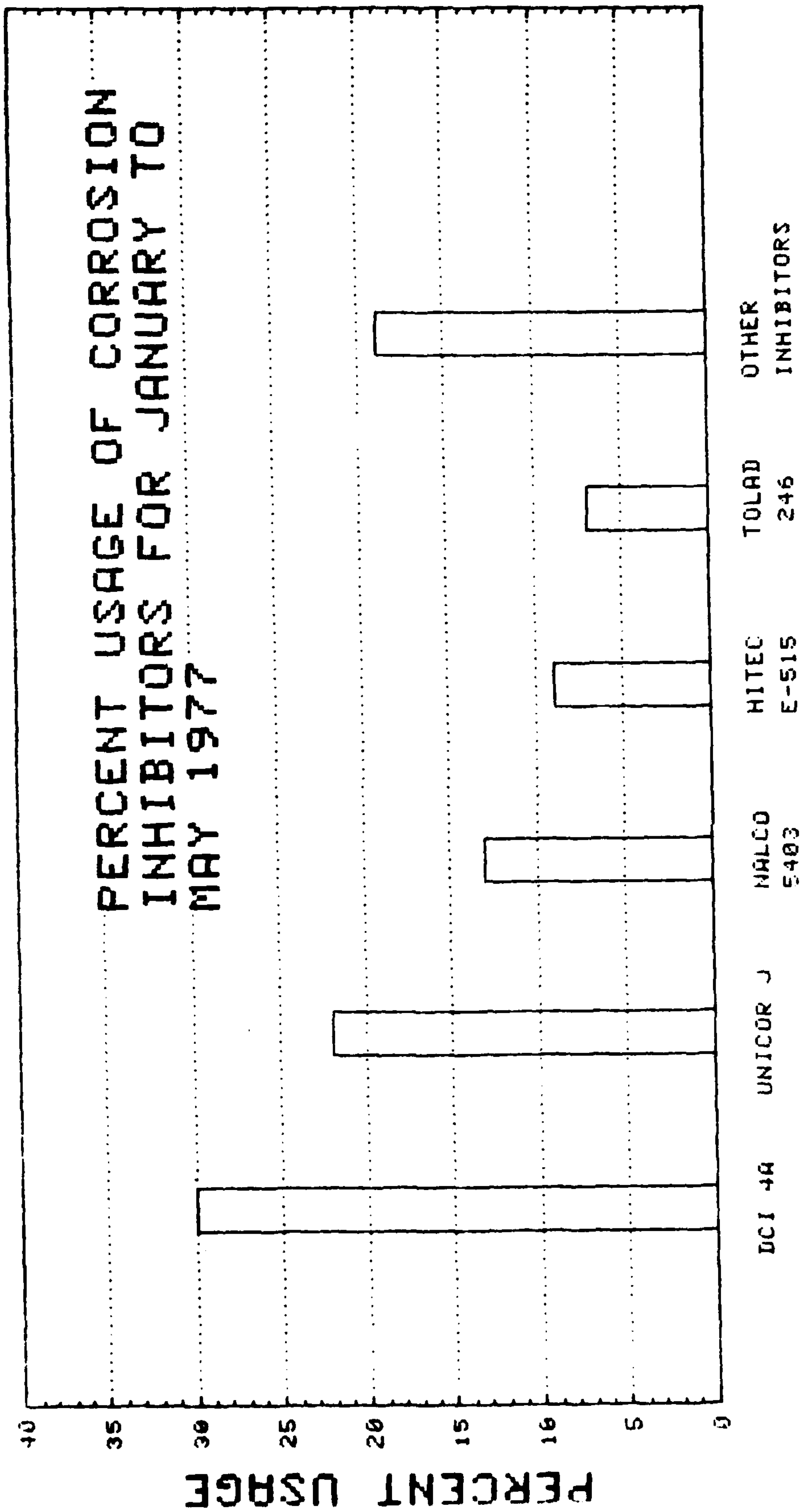


Figure 2. Usage Rate for Corrosion Inhibitors, 1977

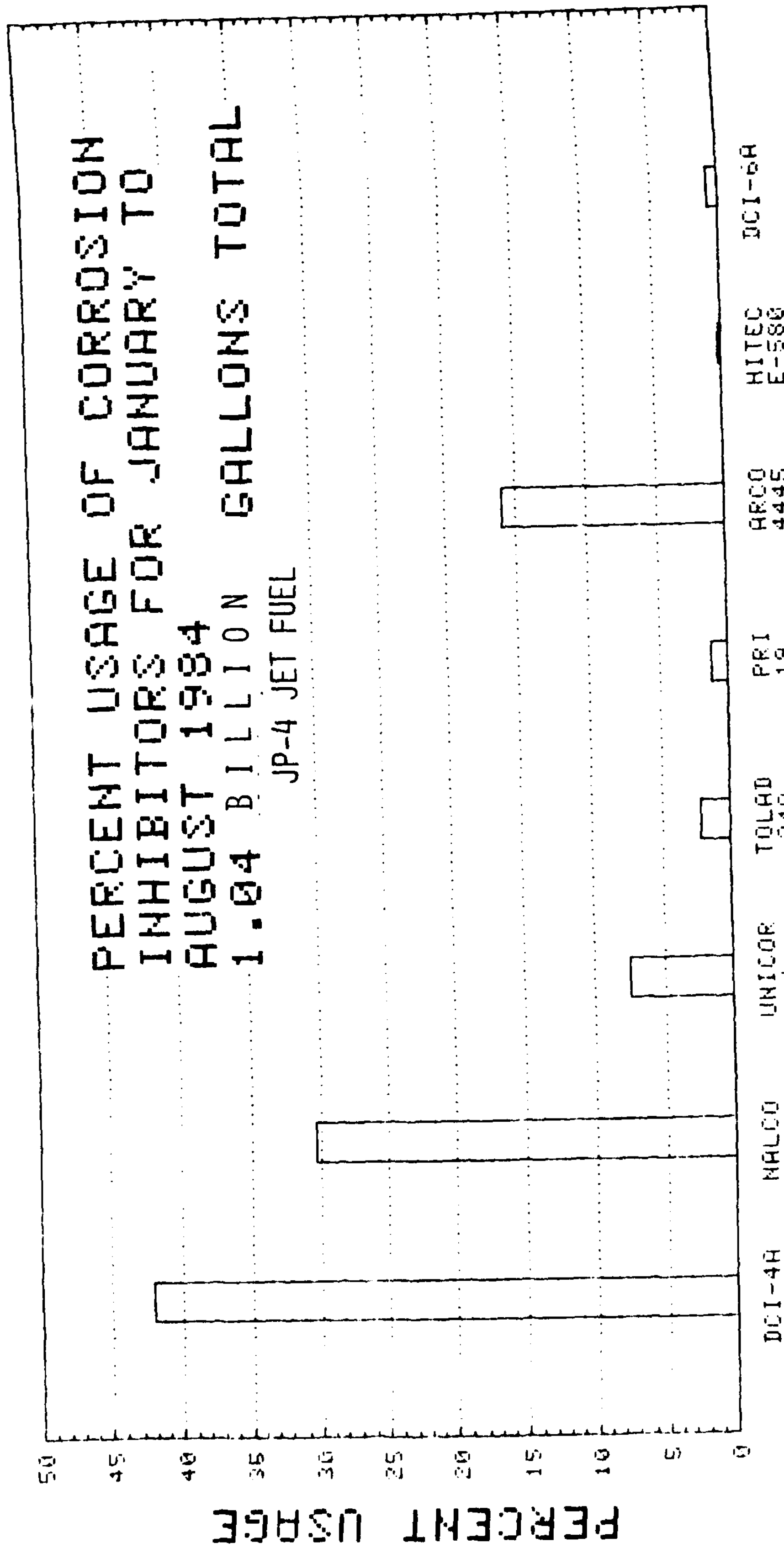


Figure 3. Usage Rate for Corrosion Inhibitors, 1984

3. RESULTS AND DISCUSSION

a. Overview

The following points, discussed in the next three sections are summarized here:

(1) Of 14 corrosion inhibitors, three showed serious deleterious effects on the conductivity of jet fuel with anti-static additive: Apollo PRI-19, Lubrizol 541, and HITEC E515.

(2) Although contradictions in the three phases were observed for the other two inhibitors, HITEC E515 in STADIS 450 always showed a decrease in electrical conductivity of more than 40% for every fuel.

(3) Fuel type did not seem to have an effect on conductivity. The isooctane/toluene mixture gave inconsistent results.

b. Phase I: Effect of 14 Corrosion Inhibitors on the Conductivity of JP-4 with ASA-3 Anti-static Additives

Since clay-treating removes all anti-static additives, corrosion inhibitors, antioxidants, metal deactivators, etc., from a fuel, the initial conductivity of the base fuel was nearly zero. The conductivity of the fuel increased to 420 pS/m with the addition of 0.571 ppm of ASA-3. The change in conductivity of baseline fuel with corrosion inhibitors (for Phase I) is listed in Table 3. As stated earlier, if the change in conductivity was greater than 40%, the concentration of corrosion inhibitor was reduced by 1 lb/1000 bbls. Table 3 indicates three corrosion inhibitors that showed changes of more than 40% for some or all concentrations of the inhibitors. This point is more easily demonstrated in Figure 4.

Also included in this section is a graph showing the change in conductivity of the base fuel over a two month period (Figure 5). This figure shows that container deactivation procedures were effective in providing consistent conductivity readings over a long period of time.

TABLE 3. RESULTS FOR PHASE I: ASA-3 IN JP-4

INHIBITOR	MIN/MAX (lbs/1000 bbls)	CONCENTRATION (lbs/1000 bbls)	PERCENT CHANGE
APOLLO PRI-19	3-8	8.60	-53.4
		7.00	-50.5
		6.02	-44.4
		5.01	-40.8
		4.00	-36.7
ARCO 4410	3-8	8.03	-30.0
DCI-4A	3-8	8.00	-13.9
DCI-6A	3-8	8.00	-13.4
HITEC E-515	7.5-16	16.00	-61.6
		7.5*	-57.2
HITEC E-580	3-8	8.00	-23.7
LUBRIZOL 541	3-6	6.22	-55.9
		3.00*	-43.6
MOBILAD F-800	3-8	8.00	- 6.2
NALCO 5403	3-8	7.98	-16.7
NALCO 5405	3-8	7.91	-10.1
P3305 (Emery)	4.5-12	12.01	- 7.0
TOLAD 245	7.5-12	12.30	-36.7
TOLAD 249	3-8	8.02	-11.8
UNICOR J	3-8	8.02	-39.0

*These were not decreased by 1 lb/1000 bbl increments - assumption made that if minimum effective and maximum allowable concentrations show greater than +/-40% change, all allowable concentrations will show greater than +/-40% change.

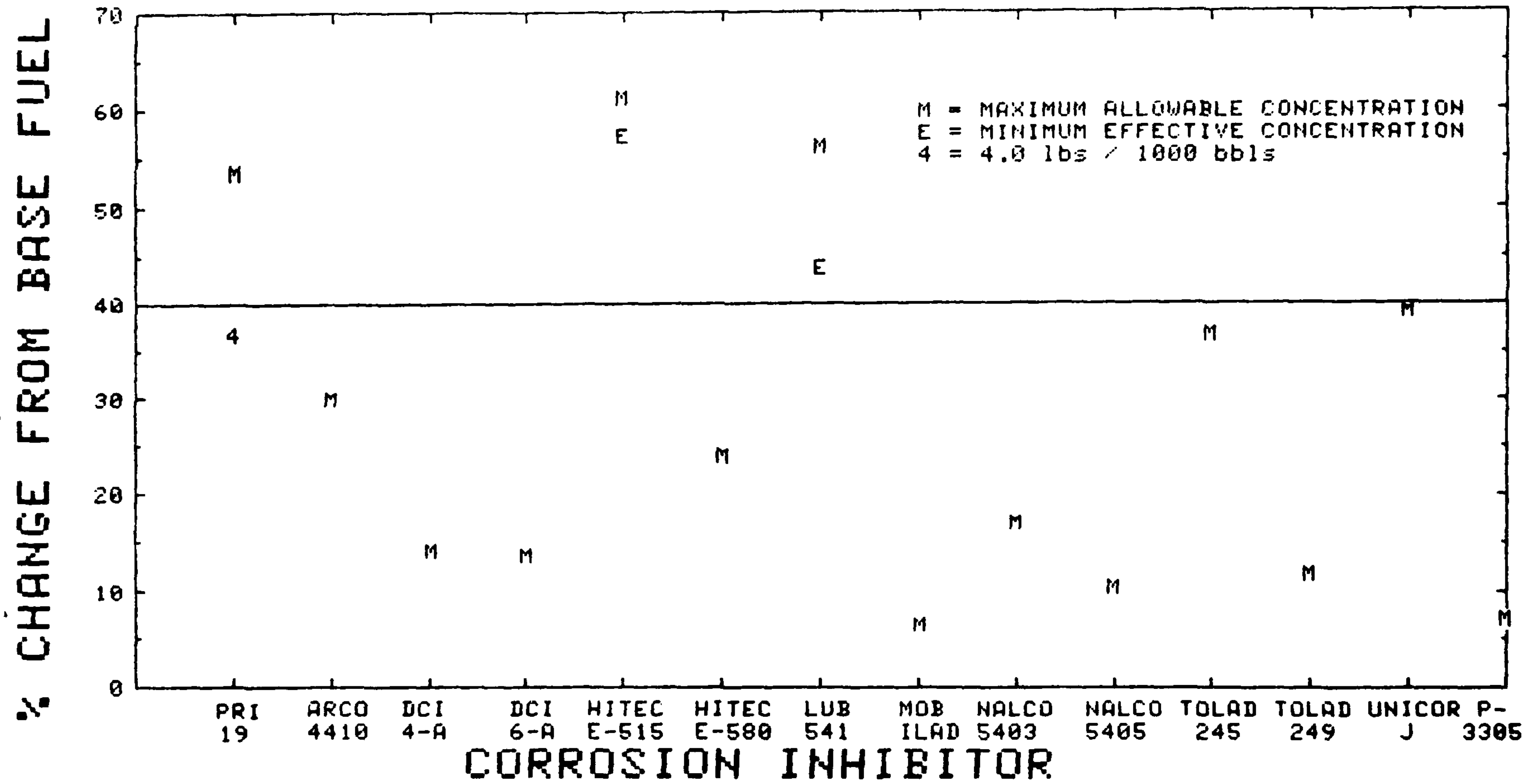


Figure 4. Effect of 14 Corrosion Inhibitors on the Conductivity of JP-4 with ASA-3

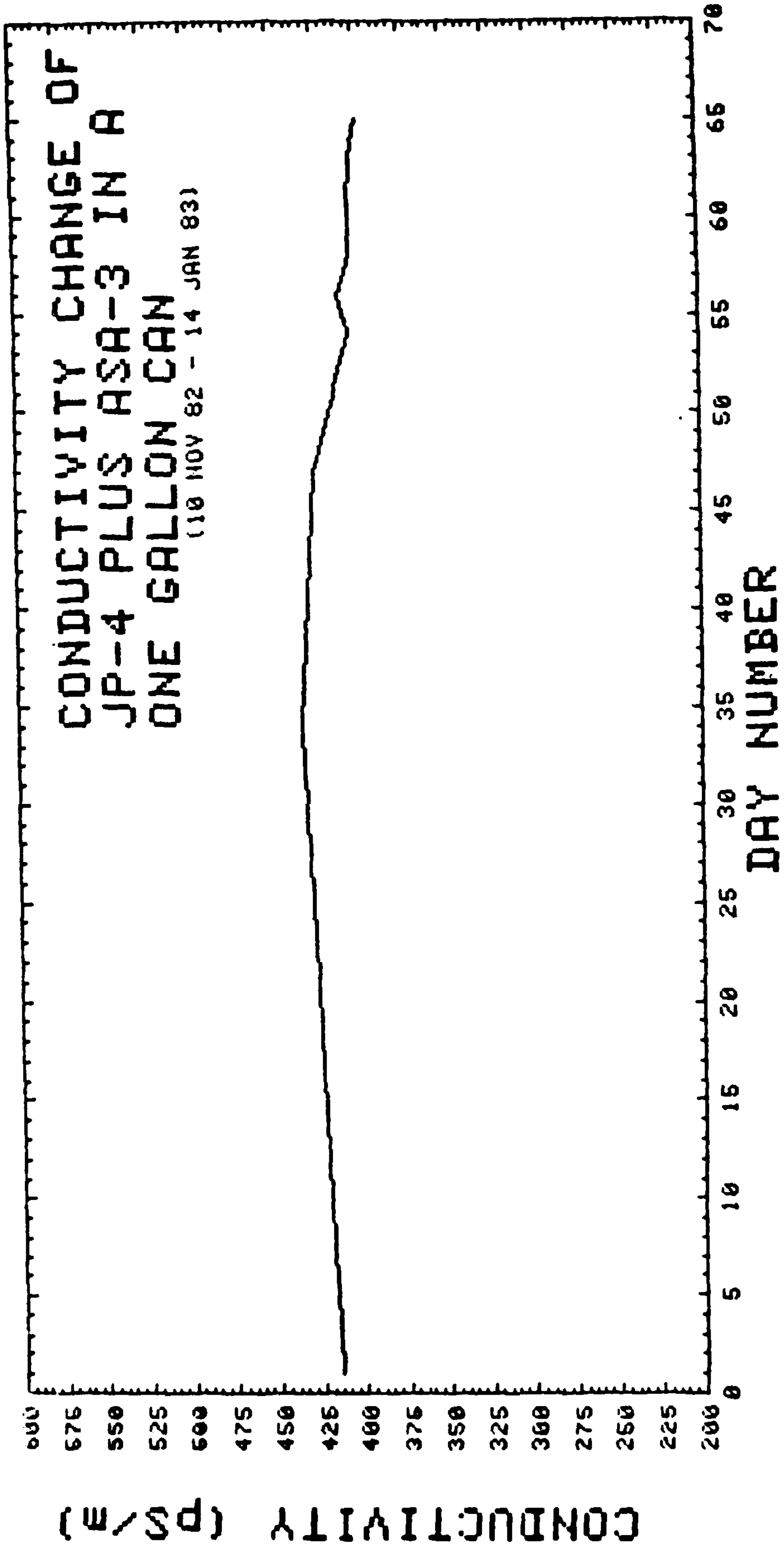


Figure 5. Conductivity Change for Base Fuel: Phase I

The results of Phase I (Table 3), show that corrosion inhibitors generally decrease the conductivity of JP-4 with ASA-3; that is, none of the corrosion inhibitors blended with ASA-3 in JP-4 caused an increase in electrical conductivity. Figure 4 shows that two inhibitors, HITEC E515 and Lubrizol 541, decrease electrical conductivity by more than 40% at all concentrations (according to the Phase I study). One inhibitor, Apollo PRI-19, produced a decrease of more than 40% for some higher concentrations and less than 40% for lower concentrations. According to the guidelines listed in the military specification for corrosion inhibitors, HITEC E515 and Lubrizol 541 would be considered "failures" and the PRI-19 would be considered "borderline" in compatibility with anti-static additives.

Since most of the corrosion inhibitors have dimer acids as their active ingredients, there seems to be no plausible explanation for the difference in the inhibitor's ability to alter conductivity. There are however, slight differences between some of these substances. For example, HITEC E515 is the only approved corrosion inhibitor containing phosphorous. The effect (if any) of phosphorous on conductivity is not well understood; one can only speculate that these slight differences initiate interactions with the fuel or antistatic additives causing variations in a fuel's ability to conduct electrical charge.

It should be pointed out here, however, that the corrosion inhibitor used in Phase I were less than one year old when the study began. At the completion of the study, the inhibitors were more than one year old. According to the military specification for corrosion inhibitors, the age of the additives to be tested should be less than one year; unfortunately, the testing was not completed before that time. This point may help to explain the differences between some of the results in later studies.

c. Phase II: Effect of 14 Corrosion Inhibitors on the Conductivity of JP-4 with STADIS 450 and TOLAD 511 Anti-Static Additives

This phase of testing was exactly like the Phase I testing except that different static dissipator additives were used. Clay-treated JP-4 fuel (the same lot that was used in Phase I) was blended to 0.56 ppm STADIS 450 in one 55 gallon drum and to 2.11 ppm TOLAD 511 in another drum. The conductivities of the "STADIS" and "TOLAD" drums were 470 pS/m and 376 pS/m, respectively. The change in conductivity with respect to the baseline fuel is listed in Table 4. This table

TABLE 4. RESULTS FOR PHASE II: STADIS -450 IN JP-4

INHIBITOR	MIN/MAX (lbs/1000 bbls)	CONCENTRATION (lbs/1000 bbls)	PERCENT CHANGE
APOLLO PRI-19	3-8	8.06	-67
		7.05	-65
		6.03	-65
		5.05	-58
		4.00	-53
		3.02	-50
ARCO 4410	3-8	8.00	-21
DCI-4A	3-8	7.96	-08
DCI-6A	3-8	8.00	-21
HITEC E-515	7.5-16	16.00	-85
		14.00	-84
		12.00	-84
		10.00	-83
		8.00	-81
		7.50	-82
HITEC E-580	3-8	8.03	-10
LUBRIZOL 541	3-6	6.00	-36
MOBILAD F-800	3-8	8.00	-11
NALCO 5403	3-8	7.98	-09
NALCO 5405	3-8	7.91	-31
P3305	4.5-12	12.01	-09
TOLAD 245	7.5-12	12.30	-30
TOLAD 249	3-8	8.02	-29
UNICOR J	3-8	8.02	-07

shows that two of the corrosion inhibitors, namely, HITEC E515 and Apollo PRI-19, produced changes of more than 40% in a STADIS 450 doped fuel for all allowable concentrations. Figure 6 illustrates this data. The slightly higher changes in conductivity as compared to the Phase I study indicate a greater interaction between STADIS 450, PRI-19 and HITEC E515 than with ASA-3, PRI-19 and HITEC E515. On the other hand, the interaction between ASA-3 and Lubrizol 541 is greater than that of STADIS 450 and Lubrizol 541. While all concentrations of Lubrizol resulted in conductivity changes greater than 40% with ASA-3, even the maximum concentration of Lubrizol with STADIS 450 gave just less than 40% change in conductivity.

It should be noted that the corrosion inhibitors with the greatest usage rate (see Figure 2) are not the same corrosion inhibitors which show conductivity changes of more than 40%. DCI-4A and NALCO 5403, which account for approximately 73% of reported corrosion inhibitor usage (1984) show very little conductivity change with either STADIS 450 or ASA-3. TOLAD 249, Unicor J, and Apollo PRI-19 produce conductivity effects which are generally higher than 30% but less than 40%.

Table 5 describes the results for JP-4 with TOLAD 511 static dissipator additive. The results for this candidate jet fuel additive show that none of the 14 corrosion inhibitors caused a change in conductivity of more than 40% from the baseline fuel. Use of this additive may relieve any adverse conductivity effects; however, this additive is not yet approved for use in aviation turbine fuel. It is also interesting to note that JP-4 requires almost four times the amount of TOLAD 511 to achieve the same conductivity as compared to ASA-3 and STADIS 450 (Table 1). Thus, this static dissipator additive does not appear to be economically advantageous for fuel blending even though conductivity effects are reduced by using this additive.

d. Phase III: Effect of Three Corrosion Inhibitors on Six Different Fuels with ASA-3 and STADIS 450 Anti-Static Additives

As was stated earlier, the purpose of Phase III testing was to re-examine "borderline" or "failing" corrosion inhibitors in different fuel types with two different anti-static additives. Original additives samples were discarded since they were more than one year old. New samples of HITEC E515, Lubrizol 541, and Apollo PRI-19 were used in this phase of the study.

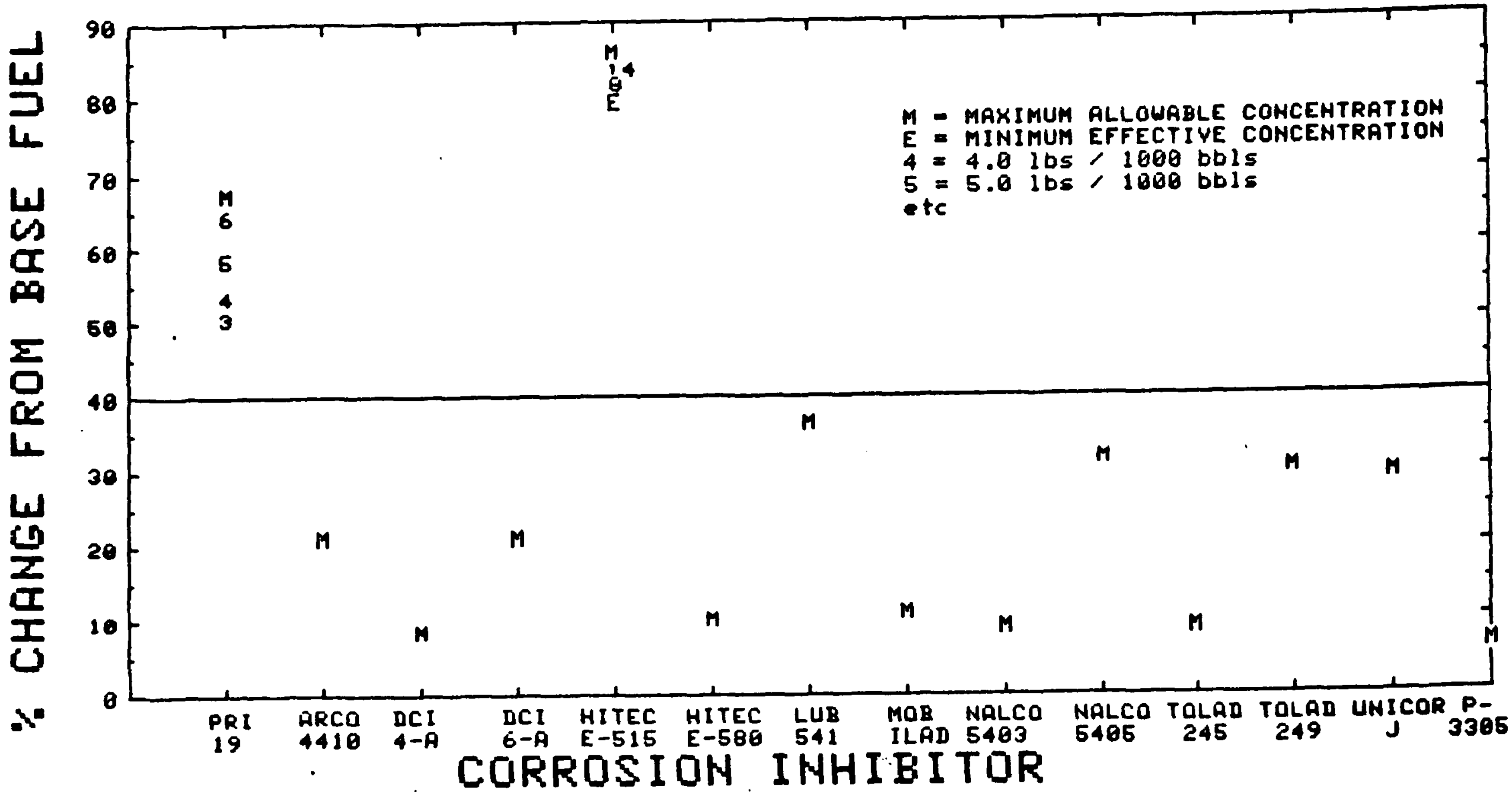


Figure 6. Effect of 14 Corrosion Inhibitors on the Conductivity of JP-4 with STADIS 450

TABLE 5. RESULTS FOR PHASE II: TOLAD-511 IN JP-4

INHIBITOR	MIN/MAX (lbs/1000 bbls)	CONCENTRATION (lbs/1000 bbls)	PERCENT CHANGE
APOLLO PRI-19	3-8	7.96	-30
ARCO 4410	3-8	7.92	-26
DCI-4A	3-8	8.00	-20
DCI-6A	3-8	7.96	-24
HITEC E-515	7.5-16	16.13	-19
HITEC E-580	3-8	8.00	-10
LUBRIZOL 541	3-6	6.00	-27
MOBILAD F-800	3-8	7.96	-21
NALCO 5403	3-8	8.03	-11
NALCO 5405	3-8	7.92	-19
P3305	4.5-12	12.00	-08
TOLAD 245	7.5-12	11.96	-21
TOLAD 249	3-8	8.00	-22
UNICOR J	3-8	8.00	-17

Apollo PRI-19 results with ASA-3 and STADIS 450 are given in Table 6. The percent change for this additive with either static dissipator additive is less than 40% for all fuels. Lubrizol 541, on the other hand (Table 7), showed increased conductivity when added with ASA-3. In nearly all cases, greater than 40% increase in conductivity was observed for the range of allowable concentrations. Lubrizol 541 with STADIS 450 however, did not demonstrate a significant change in conductivity. The last inhibitor, HITEC E515 (shown in Table 8), produced less than 40% change with ASA-3 for all but one fuel. With STADIS 450 however, HITEC E515 caused fuel conductivity to decrease by more than 40% for every concentration and in every fuel.

The results for Tables 6, 7, and 8 are described graphically in Figures 7, 8, and 9.

The most interesting result of the third study was the fact that contradictions were observed from the initial studies. For JP-4 with ASA-3, Lubrizol 541 brought about decreases in base fuel conductivity of more than 40% for all concentrations of this inhibitor. Phase III studies for the same JP-4 revealed an increase in conductivity of more than 40% for 6 and 5 lbs per 1000 bbls (all other concentrations showed just less than 40% increase). Similar results were observed for other fuel types. These apparent contradictions could not be explained. It is possible that the new, fresh sample of Lubrizol produced a different effect than the slightly aged sample. Other differences were apparent in Phase III. HITEC E515 did not show an increase of more than 40% for ASA-3 in any type of fuel (Table 8) with the exception of the isooctane/toluene mixture. Apollo PRI-19 showed similar results.

For STADIS 450 in any type of fuel, Apollo PRI-19 and Lubrizol did not show a decrease of more than 40% for any allowable concentration. Phase II, however, did show greater increases. HITEC E515 with STADIS 450 showed a decrease in electrical conductivity of more than 40% for every fuel.

TABLE 6. RESULTS FOR PHASE III: APOLLO PRI-19

Fuel No., Type	Static Dissipator Additive	Corrosion Inhibitor Concentration (lbs/1000 bbls)	Percent Change from Base fuel
-0708 (JP-4)	ASA-3	8.0	-02
-0883 (JET A)	ASA-3	8.0	+04
-0113 (Shale JP-4)	ASA-3	8.0	-18
-1330 (JP-4)	ASA-3	8.0	-06
-1329 (JP-8)	ASA-3	8.0	-19
-1333 (*)	ASA-3	8.0	-03
-0708 (JP-4)	STADIS 450	8.0	-27
-0883 (JET A)	STADIS 450	8.0	-27
-0113 (Shale JP-4)	STADIS 450	8.0	-34
-1330 (JP-4)	STADIS 450	8.0	-30
-1329 (JP-8)	STADIS 450	8.0	-33
-1333 (*)	STADIS 450	8.0	-24

*70% iso-octane/30% toluene by volume

TABLE 7. RESULTS FOR PHASE III: LUBRIZOL 541

Fuel No., Type	Static Dissipator Additive	Corrosion Inhibitor Concentration (lbs/1000 bbls)	Percent Change from Base fuel
-0708 (JP-4)	ASA-3	6.0	+43
		5.0	+30
-0883 (JET A)	ASA-3	6.0	+55
		5.0	+50
		4.0	+54
		3.0	+54
-0113 (Shale JP-4)	ASA-3	6.0	+44
		5.0	+50
		4.0	+47
		3.0	+43
-1330 (JP-4)	ASA-3	6.0	+42
		5.0	+38
		4.0	+32
-1329 (JP-8)	ASA-3	6.0	+42
		5.0	+35
-1333 (*)	ASA-3	6.0	+34
-0708 (JP-4)	STADIS 450	6.0	-16
-0883 (JET A)	STADIS 450	6.0	-21
-0113 (Shale JP-4)	STADIS 450	6.0	-18
-1330 (JP-4)	STADIS 450	6.0	-11
-1329 (JP-8)	STADIS 450	6.0	-11
-1333 (*)	STADIS 450	6.0	-28

*70% iso-octane/30% toluene by volume

TABLE 8. RESULTS FOR PHASE III: HITEC E-515

Fuel No., Type	Static Dissipator Additive	Corrosion Inhibitor Concentration (lbs/1000 bbls)	Percent Change from Base fuel
-0708 (JP-4)	ASA-3	16.0	-13
-0883 (JET A)	ASA-3	16.0	-10
-0113 (Shale JP-4)	ASA-3	16.0	-29
-1330 (JP-4)	ASA-3	16.0	-18
-1329 (JP-8)	ASA-3	16.0	-21
-1333 (*)	ASA-3	16.0	+64
		14.0	+52
		12.0	+71
		10.0	+82
		8.0	+147
		7.5	+112
-0708 (JP-4)	STADIS 450	16.0	-64
		14.0	-64
		12.0	-64
		10.0	-64
		8.0	-63
		7.5	-63
-0883 (JET A)	STADIS 450	16.0	-66
		14.0	-68
		12.0	-67
		10.0	-65
		8.0	-62
		7.5	-62
		16.0	-71
-0113 (Shale JP-4)	STADIS 450	14.0	-70
		12.0	-70
		10.0	-70
		8.0	-68
		7.5	-68
-1330 (JP-4)	STADIS 450	16.0	-67
		14.0	-68
		12.0	-70
		10.0	-67
		8.0	-65
		7.5	-66
		16.0	-70
-1329 (JP-8)	STADIS 450	14.0	-68
		12.0	-68
		10.0	-68
		8.0	-64
		7.5	-64
		16.0	-52

TABLE 8. (Concluded)

-1333 (*)	STADIS 450	14.0	-51
		12.0	-53
		10.0	-53
		8.0	-54
		7.5	-53

*70% iso-octane/80% Toluene by Volume

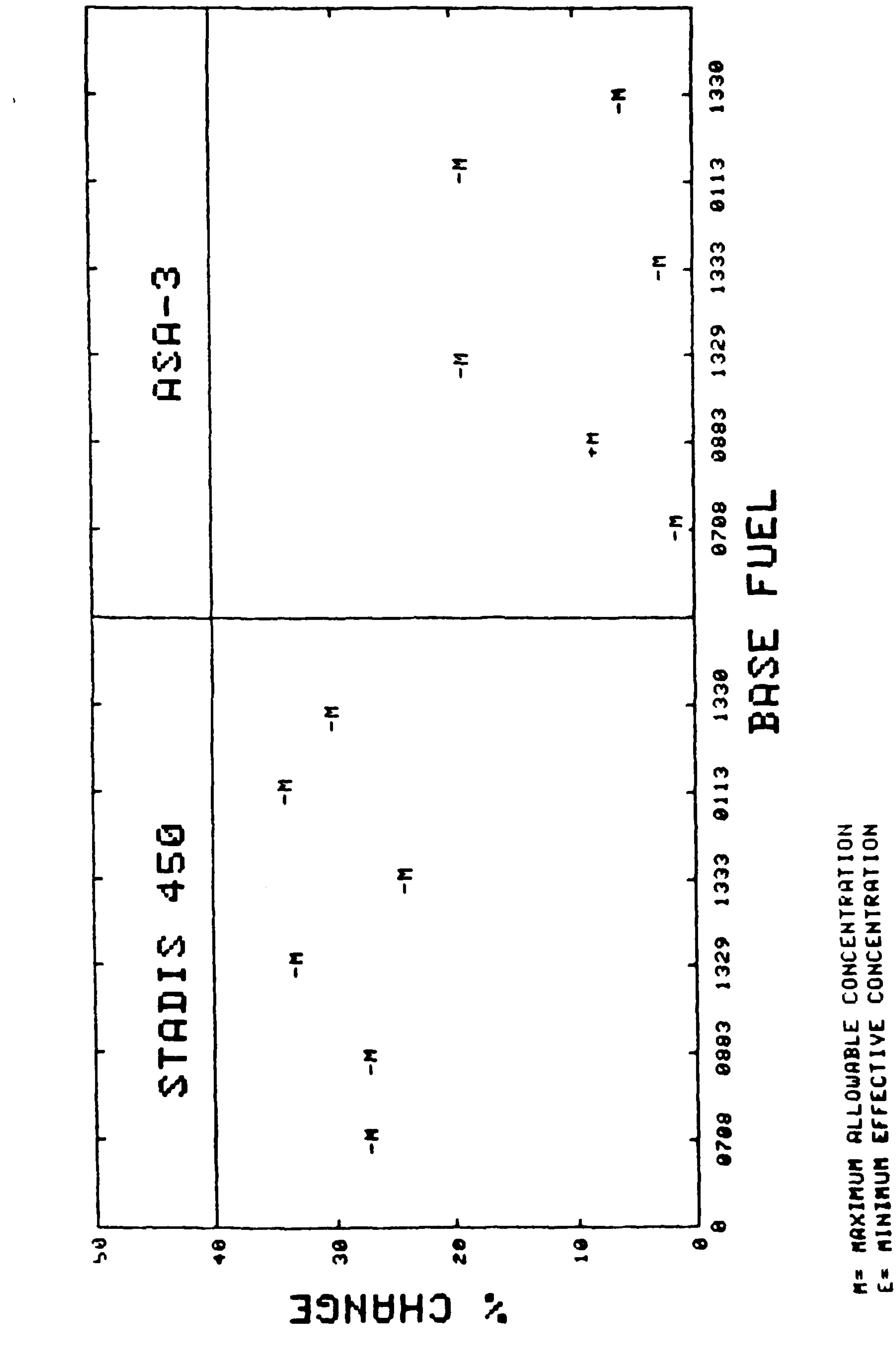
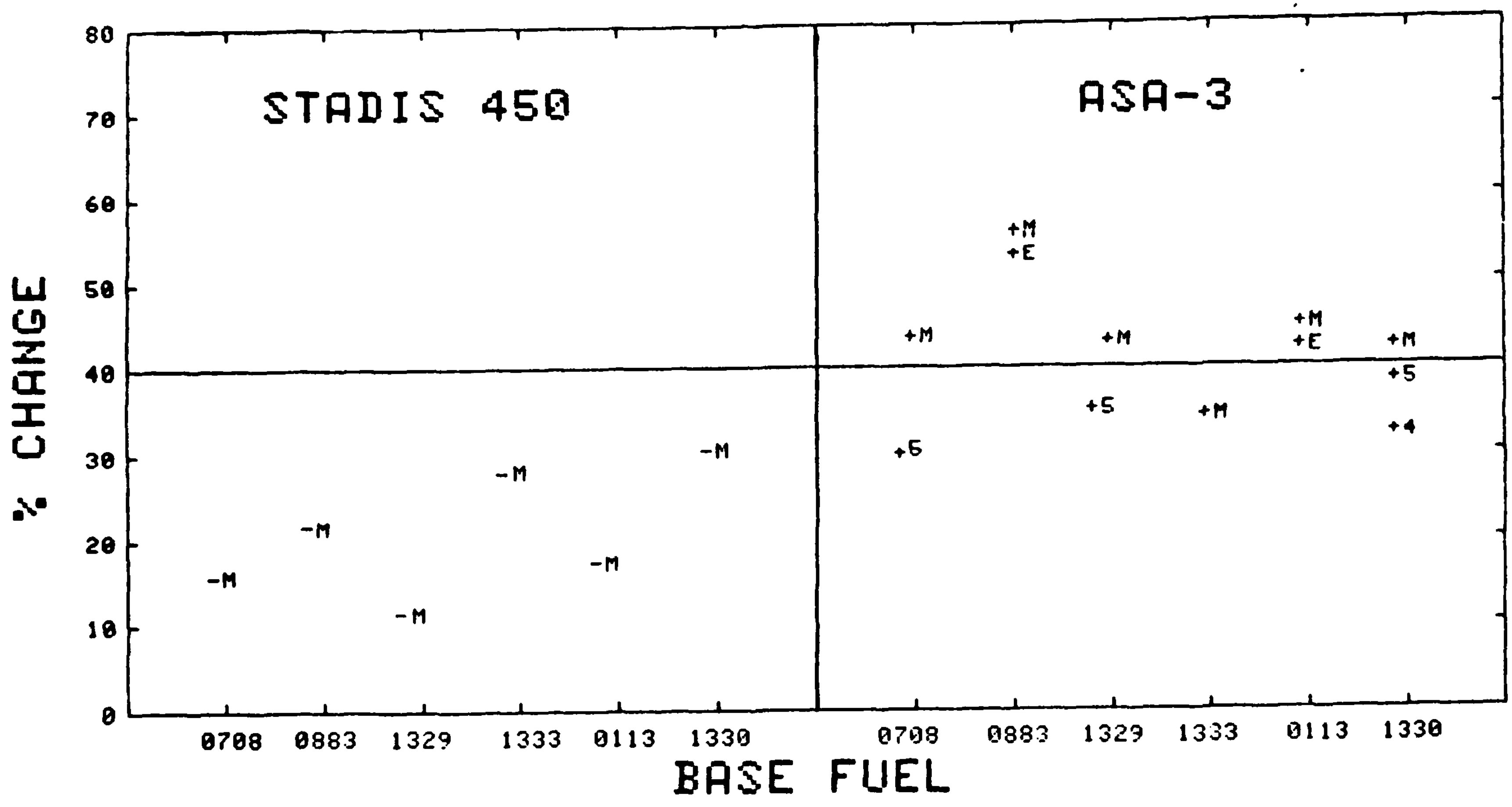


Figure 7. Results for Apollo PRI-19: Phase III



M= MAXIMUM ALLOWABLE CONCENTRATION
E= MINIMUM EFFECTIVE CONCENTRATION
5= 5.0 LBS/1000 BBLS

Figure 8. Results for Lubrizol 541: Phase III

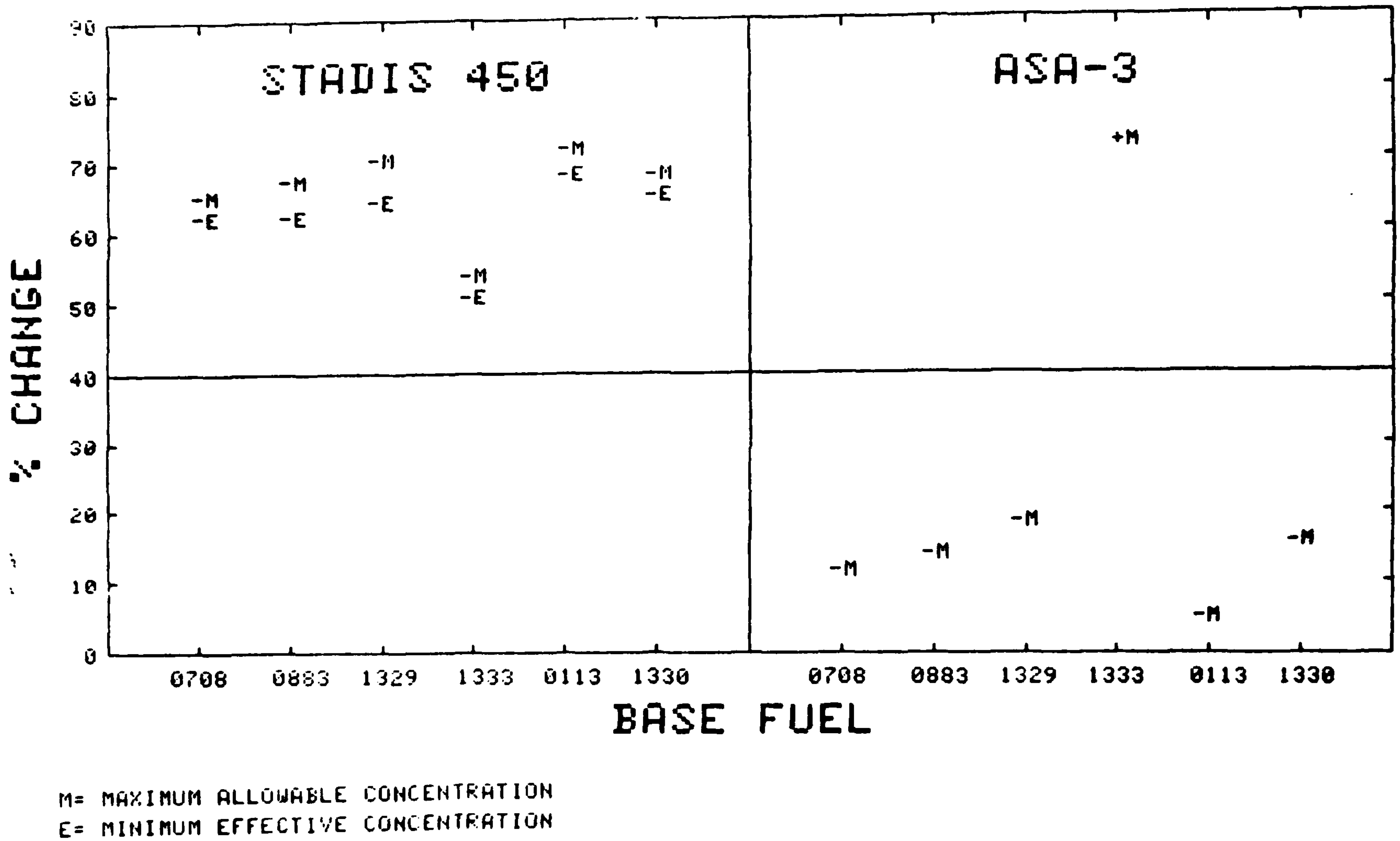


Figure 9. Results for HITEC E515: Phase III

SECTION III

RECOMMENDATIONS

Because of the results shown from these studies, the Air Force (Fuels and Lubrication Division, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) has removed the corrosion inhibitor HITEC E515 from the Qualified Products List. A decrease in conductivity of more than 40% resulted when HITEC E515 was blended with STADIS 450 anti-static additive in any fuel type. Since corrosion inhibitors must be compatible with all approved additives according to MIL-I-25017D, HITEC E515 is now justifiably omitted from the list.

The recommendation regarding Lubrizol 541 was less clear cut. When tested in fuels containing ASA-3 there were three failures at all concentrations, three partial failures (i.e., failed at maximum allowable concentration but passed at minimum effective concentration), and one pass at maximum allowable concentration . However, with Stadis 450 there were no failures or partial failures. Since Lubrizol 541 is the only corrosion inhibitor on the QPL-25017 that is approved for use in MIL-G-5572 aviation gasolines, it was recommended that it remain on the QPL.

The other corrosion inhibitor, Apollo PRI-19 gave results which did not demonstrate consistent incompatibility.

In the past three years, the Air Force has become involved with the processing and use of fuel from shale oil. Since nitrogen, sulfur and aromatic levels are higher than petroleum crudes, shale crude oil must be highly hydro-refined before using as an aviation fuel. Unfortunately, the severe hydrotreating can decrease the lubricity of the shale fuel such that fuel pump wear is more likely than with fuel produced from conventional petroleum crudes. Also, as these crude sources diminish, "heavier" crudes (higher in aromatics, contaminants) will be utilized. Greater amounts of hydroprocessing will again be necessary, decreasing fuel lubricity.

In order to improve fuel lubricity, corrosion inhibitors have been added to shale-derived fuels to be used in aircraft engine testing (References 10 and 11). This experience has shown that corrosion inhibitors must be added in their maximum allowable concentrations to produce a fuel with an acceptable lubricity level.

Corrosion inhibitors, by their very nature, tend to adhere to metal surfaces in order to prevent oxygen from easily migrating to the metal to begin the oxidation process. Thus, many jet fuel users will discover that corrosion inhibitor content will decrease during fuel handling operations where the additive "plates out" on untreated metal surfaces. In order to combat this decrease in lubricating ability because of corrosion inhibitor loss, military users of jet fuel are preparing, if necessary, to add additional corrosion inhibitor upon receipt of jet fuel at the base level. Conductivity effects from an increased dosage of corrosion inhibitor will be more apparent. At the very least, users of hydro-refined fuel should be aware that addition of these inhibitors to improve lubricity may have detrimental effects on static conductivity.

In conclusion, as more corrosion inhibitor is used to enhance the lubricity of alternate-source aviation turbine fuels, electrical conductivity may be affected to a greater degree than at present. Studies such as this will be necessary to control the use of inhibitors which significantly decrease conductivity. Conductivity should also be of concern when evaluating candidate lubricity and anti-corrosion additives. Electrical conductivity will continue to be an important property for the aviation turbine fuels of the present as well as the future.

REFERENCES

1. MIL-T-5624L, Military Specification, Turbine Fuel, Aviation Grades JP-4 and JP-5, 10 Aug 1983.

2. MIL-I-25017D, Military Specification, Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble, 27 May 1981.

3. ASTM D 2250, 1982 Annual Book of ASTM Standards, Petroleum Products and Lubricants, Part 24, Philadelphia PA.

4. ASTM D 2624, 1982 Annual Book of ASTM Standards, Petroleum Products and Lubricants, Part 24, Philadelphia PA.

5. ASTM D 3114, 1982 Annual Book of ASTM Standards, Petroleum Products and Lubricants, Part 24, Philadelphia PA.

6. Qualified Products List, QPL-25017-13, QPL for Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble, 31 Oct 1980.

7. STADIS 450 Product Description

8. TOLAD 511 Product Description

9. Hayes. P. C., "AFAPL In-House Anti-Static Additive Compatibility Study," February 1977 - April 1978, Wright-Patterson AFB OH 45433-6563.

10. Striebich, R. C., and Dues, T. L., F100 Test Fuel Properties, March 1984.

11. Striebich, R. C., and Dues, T. L., TF30 Test Fuel Properties, June 1984.

APPENDIX A

EFFECT OF CORROSION INHIBITORS ON CONDUCTIVITY OF JP-4 FUEL CONTAINING ASA-3 ADDITIVE

Conductivity of Base Fuel, pS/m Initial	Final	Average	Inhibitor	Inhibitor Concentration lb/1000 bbls	Conductivity with Inhibitor pS/m
421	423	422	PRI-19	8.6	197
423	437	430		7.00	213
423	437	430		6.02	239
417	405	411		5.01	243
417	405	411		4.00	260
420	437	428	ARCO4410	8.03	310
420	437	428	DCI-4A	8.00	369
422	430	426	DCI-6A	8.00	369
422	430	426	HITEC E-515	16.04	166
422	430	426		16.04	172
422	430	426		7.50	182
422	430	426	HITEC E-580	8.00	325
422	430	426	LUBRIZOL 541	6.22	186
424	425	425		3.00	239
422	423	423	MOBILAD	8.00	396
430	424	427	NALCO 5403	7.96	355
430	423	427	NALCO 5405	7.91	384
425	408	417	TOLAD 245	12.3	264
425	408	417		11.0	274
408	423	416	TOLAD 249	8.02	367
408	424	416	UNICOR J	8.02	254
408	424	416		7.00	270
426	408	417	P3305	12.01	388

APPENDIX B

EFFECT OF CORROSION INHIBITORS ON CONDUCTIVITY OF FUEL CONTAINING TOLAD-511 ADDITIVE

Conductivity of Base Fuel, ps/m			Inhibitor	Inhibitor Concentration lb/1,000 bbl	Conductivity with Inhibitor, ps/m
Initial	Final	Average			
376	372	374	APOLLO PRI-19	7.96	262
376	372	374	ARCO 4410	7.92	278
376	372	374	DCI-4A	8.00	299
376	372	374	DCI-6A	7.96	282
376	372	374	HITEC E-515	16.13	302
376	340	358	HITEC E-580	8.00	322
376	340	358	LUBRIZOL 541	6.00	262
376	340	358	MOBILAD F-800	7.96	282
376	343	360	NAKO 5403	8.03	319
376	343	360	NAKO 5405	7.92	293
376	343	360	P3305	12.00	333
376	343	360	TOLAD 245	11.96	286
376	343	360	TOLAD 249	8.00	282
376	343	360	UNICOR J	8.00	298

APPENDIX B (con't)

EFFECT OF CORROSION INHIBITORS ON CONDUCTIVITY OF FUEL CONTAINING STADIS 450 ADDITIVE

Conductivity of Base Fuel, ps/m				Inhibitor Concentration	Conductivity with Inhibitor,
Initial	Final	Average	Inhibitor	lb/1,000 bbl	ps/m
474	479	476	APOLLO PRI-19	8.06	157
				7.05	168
474	462	468		6.03	164
				5.05	198
				4.00	219
474	493	484		3.02	243
474	493	484	ARCO 4410	8.00	380
474	493	484	DCI-4A	7.96	445
474	493	484	DCI-6A	8.00	383
474	493	484	HITEC E-515	16.00	72
				14.00	78
				12.00	78
				10.00	82
				8.00	92
474	490	482		7.50	89
474	467	470	HITEC E-580	8.03	423
474	467	470	LUBRIZOL 541	6.00	302
474	467	470	MOBILAD F-800	8.03	416
474	470	472	NALCO 5403	8.00	430
474	470	472	NALCO 5405	8.00	326
474	470	472	P3305	12.00	430
474	470	472	TOLAD 245	12.00	329
474	470	472	TOLAD 249	8.03	333
474	470	472	UNICOR J	8.03	437

APPENDIX C

ELECTRICAL CONDUCTIVITY OF FUELS

Sample Identification	Antistatic Additive	Corrosion Inhibitor Added	Conc (lb/1000 bbl)	Average Conductivity (pS/m)
83-POSF-0708 Base Fuel	Stadis 450	None	-	474
83-POSF-0708 Base Fuel	Stadis 450	None	-	541
83-POSF-0708 Base Fuel	Stadis 450	None	-	534
83-POSF-0708 Base Fuel	Stadis 450	None	-	527
83-POSF-0708 Base Fuel	Stadis 450	None	-	529
83-POSF-0708 Base Fuel	Stadis 450	None	-	543
83-POSF-0708 Base Fuel	Stadis 450	None	-	546
83-POSF-0708 Base Fuel	Stadis 450	None	-	550
83-POSF-0708 Base Control	Stadis 450	None	-	548
83-POSF-0708 Base Control	Stadis 450	None	-	536
83-POSF-0708 Base Control	Stadis 450	None	-	529
83-POSF-0708 Base Control	Stadis 450	None	-	534
83-POSF-0708 Base Control	Stadis 450	None	-	537
83-POSF-0708 Base Control	Stadis 450	None	-	540
83-POSF-0708 Base Control	Stadis 450	None	-	536
83-POSF-0708 Base Control	Stadis 450	None	-	534
83-POSF-0708	Stadis 450	APOLLO PRI-19	8	197
83-POSF-0708	Stadis 450	LUBRIZOL 541	6	459
83-POSF-0708	Stadis 450	HITEC E-515	16	198
83-POSF-0708	Stadis 450	HITEC E-515	14	193
83-POSF-0708	Stadis 450	HITEC E-515	12	190
83-POSF-0708	Stadis 450	HITEC E-515	10	190
83-POSF-0708	Stadis 450	HITEC E-515	8	200
83-POSF-0708	Stadis 450	HITEC E-515	7.5	200
83-POSF-0883 Base Fuel	Stadis 450	None	-	431
83-POSF-0883 Base Fuel	Stadis 450	None	-	459
83-POSF-0883 Base Fuel	Stadis 450	None	-	466
83-POSF-0883 Base Fuel	Stadis 450	None	-	459
83-POSF-0883 Base Fuel	Stadis 450	None	-	459
83-POSF-0883 Base Fuel	Stadis 450	None	-	452
83-POSF-0883 Base Fuel	Stadis 450	None	-	454
83-POSF-0883 Base Fuel	Stadis 450	None	-	466
83-POSF-0883 Base Fuel	Stadis 450	None	-	463
83-POSF-0883 Base Control	Stadis 450	None	-	461
83-POSF-0883 Base Control	Stadis 450	None	-	466
83-POSF-0883 Base Control	Stadis 450	None	-	464
83-POSF-0883 Base Control	Stadis 450	None		466
83-POSF-0883 Base Control	Stadis 450	None	-	469
83-POSF-0883 Base Control	Stadis 450	None	-	461
83-POSF-0883 Base Control	Stadis 450	None	-	481
83-POSF-0883 Base Control	Stadis 450	None	-	479
83-POSF-0883	Stadis 450	APOLLO PRI-19	8	335
83-POSF-0883	Stadis 450	LUBRIZOL 541	6	361
83-POSF-0883	Stadis 450	HITEC E-515	16	157
83-POSF-0883	Stadis 450	HITEC E-515	14	151
83-POSF-0883	Stadis 450	HITEC E-515	12	151
83-POSF-0883	Stadis 450	HITEC E-515	10	162
83-POSF-0883	Stadis 450	HITEC E-515	8	176
83-POSF-0883	Stadis 450	HITEC E-515	7.5	178

APPENDIX C (con't)

ELECTRICAL CONDUCTIVITY OF FUELS

Sample Identification	Antistatic Additive	Corrosion Inhibitor Added	Conc. (lb/1000 bbl)	Average Conductivity (pS/m)
83-POSF-1329 Base Fuel	ASA-3	None	-	513
83-POSF-1329 Base Fuel	ASA-3	None	-	589
83-POSF-1329 Base Fuel	ASA-3	None	-	571
83-POSF-1329 Base Fuel	ASA-3	None	-	520
83-POSF-1329 Base Control	ASA-3	None	-	561
83-POSF-1329 Base Control	ASA-3	None	-	539
83-POSF-1329 Base Control	ASA-3	None	-	449
83-POSF-1329	ASA-3	APOLLO PRI-19	8	466
83-POSF-1329	ASA-3	LUBRIZOL 541	6	822
83-POSF-1329	ASA-3	LUBRIZOL 541	5	751
83-POSF-1329	ASA-3	HITEC E-515	16	466
83-POSF-1330 Base Fuel	ASA-3	None	-	424
83-POSF-1330 Base Fuel	ASA-3	None	-	481
83-POSF-1330 Base Fuel	ASA-3	None	-	493
83-POSF-1330 Base Fuel	ASA-3	None	-	437
83-POSF-1330 Base Fuel	ASA-3	None	-	447
83-POSF-1330 Base Control	ASA-3	None	-	468
83-POSF-1330 Base Control	ASA-3	None	-	469
83-POSF-1330 Base Control	ASA-3	None	-	413
83-POSF-1330 Base Control	ASA-3	None	-	395
83-POSF-1330	ASA-3	APOLLO PRI-19	8	445
83-POSF-1330	ASA-3	LUBRIZOL 541	6	671
83-POSF-1330	ASA-3	LUBRIZOL 541	5	664
83-POSF-1330	ASA-3	LUBRIZOL 541	4	563
83-POSF-1330	ASA-3	HITEC E-515	16	397
82-POSF-0113 Base Fuel	ASA-3	None	-	452
82-POSF-0113 Base Fuel	ASA-3	None	-	495
82-POSF-0113 Base Fuel	ASA-3	None	-	479
82-POSF-0113 Base Fuel	ASA-3	None	-	457
82-POSF-0113 Base Fuel	ASA-3	None	-	459
82-POSF-0113 Base Fuel	ASA-3	None	-	445
82-POSF-0113 Base Control	ASA-3	None	-	486
82-POSF-0113 Base Control	ASA-3	None	-	477
82-POSF-0113 Base Control	ASA-3	None	-	454
82-POSF-0113 Base Control	ASA-3	None	-	461
82-POSF-0113 Base Control	ASA-3	None	-	449
82-POSF-0113	ASA-3	APOLLO PRI-19	8	404
82-POSF-0113	ASA-3	LUBRIZOL 541	6	708
82-POSF-0113	ASA-3	LUBRIZOL 541	5	719
82-POSF-0113	ASA-3	LUBRIZOL 541	4	669
82-POSF-0113	ASA-3	LUBRIZOL 541	3	657
82-POSF-0113	ASA-3	HITEC E-515	16	466

APPENDIX C (con't)

ELECTRICAL CONDUCTIVITY OF FUELS

Sample Identification	Antistatic Additive	Corrosion Inhibitor Added	Conc (lb/1000 bbl)	Average Conductivity (pS/m)
83-POSF-0708 Base Fuel	ASA-3	None	-	534
83-POSF-0708 Base Fuel	ASA-3	None	-	616
83-POSF-0708 Base Fuel	ASA-3	None	-	630
83-POSF-0708 Base Control	ASA-3	None	-	630
83-POSF-0708 Base Control	ASA-3	None	-	623
83-POSF-0708 Base Control	ASA-3	None	-	557
83-POSF-0708	ASA-3	APOLLO PRI-19	8	616
83-POSF-0708	ASA-3	LUBRIZOL 541	6	890
83-POSF-0708	ASA-3	LUBRIZOL 541	5	845
83-POSF-0708	ASA-3	HITEC E-515	16	548
83-POSF-0883 Base Fuel	ASA-3	None	-	383
83-POSF-0883 Base Fuel	ASA-3	None	-	386
83-POSF-0883 Base Fuel	ASA-3	None	-	411
83-POSF-0883 Base Fuel	ASA-3	None	-	390
83-POSF-0883 Base Fuel	ASA-3	None	-	385
83-POSF-0883 Base Fuel	ASA-3	None	-	356
83-POSF-0883 Base Fuel	ASA-3	None	-	363
83-POSF-0883 Base Control	ASA-3	None	-	474
83-POSF-0883 Base Control	ASA-3	None	-	431
83-POSF-0883 Base Control	ASA-3	None	-	424
83-POSF-0883 Base Control	ASA-3	None	-	429
83-POSF-0883 Base Control	ASA-3	None	-	399
83-POSF-0883 Base Control	ASA-3	None	-	392
83-POSF-0883	ASA-3	APOLLO PRI-19	8	436
83-POSF-0883	ASA-3	LUBRIZOL 541	6	623
83-POSF-0883	ASA-3	LUBRIZOL 541	5	630
83-POSF-0883	ASA-3	LUBRIZOL 541	4	628
83-POSF-0883	ASA-3	LUBRIZOL 541	3	625
83-POSF-0883	ASA-3	HITEC E-515	16	347
83-POSF-1333 Base Fuel	ASA-3	None	-	554
83-POSF-1333 Base Fuel	ASA-3	None	-	958
83-POSF-1333 Base Fuel	ASA-3	None	-	1118
83-POSF-1333 Base Fuel	ASA-3	None	-	1050
83-POSF-1333 Base Fuel	ASA-3	None	-	913
83-POSF-1333 Base Fuel	ASA-3	None	-	667
83-POSF-1333 Base Fuel	ASA-3	None	-	639
83-POSF-1333 Base Fuel	ASA-3	None	-	748
83-POSF-1333 Base Fuel	ASA-3	None	-	765
83-POSF-1333 Base Control	ASA-3	None	-	876
83-POSF-1333 Base Control	ASA-3	None	-	1050
83-POSF-1333 Base Control	ASA-3	None	-	856
83-POSF-1333 Base Control	ASA-3	None	-	879
83-POSF-1333 Base Control	ASA-3	None	-	698
83-POSF-1333 Base Control	ASA-3	None	-	648
83-POSF-1333 Base Control	ASA-3	None	-	730
83-POSF-1333 Base Control	ASA-3	None	-	719
83-POSF-1333	ASA-3	APOLLO PRI-19	8	890
83-POSF-1333	ASA-3	LUBRIZOL 541	6	1232
83-POSF-1333	ASA-3	HITEC E-515	16	1575
83-POSF-1333	ASA-3	HITEC E-515	14	1643
83-POSF-1333	ASA-3	HITEC E-515	12	1632
83-POSF-1333	ASA-3	HITEC E-515	10	1632
83-POSF-1333	ASA-3	HITEC E-515	8	1598
83-POSF-1333	ASA-3	HITEC E-515	7.5	1563

APPENDIX C (con't)

ELECTRICAL CONDUCTIVITY OF FUELS

Sample Identification	Antistatic Additive	Corrosion Inhibitor Added	Conc. (lb/1000 bbl)	Average Conductivity (pS/m)
82-POSF-0113 Base Fuel	Stadis 450	None	-	520
82-POSF-0113 Base Fuel	Stadis 450	None	-	520
82-POSF-0113 Base Fuel	Stadis 450	None	-	507
82-POSF-0113 Base Fuel	Stadis 450	None	-	507
82-POSF-0113 Base Fuel	Stadis 450	None	-	516
82-POSF-0113 Base Fuel	Stadis 450	None	-	527
82-POSF-0113 Base Fuel	Stadis 450	None	-	534
82-POSF-0113 Base Fuel	Stadis 450	None	-	536
82-POSF-0113 Base Fuel	Stadis 450	None	-	534
82-POSF-0113 Base Control	Stadis 450	None	-	513
82-POSF-0113 Base Control	Stadis 450	None	-	500
82-POSF-0113 Base Control	Stadis 450	None	-	481
82-POSF-0113 Base Control	Stadis 450	None	-	488
82-POSF-0113 Base Control	Stadis 450	None	-	477
82-POSF-0113 Base Control	Stadis 450	None	-	470
82-POSF-0113	Stadis 450	APOLLO PRI-19	8	342
82-POSF-0113	Stadis 450	LUBRIZOL 541	6	424
82-POSF-0113	Stadis 450	HITEC E-515	16	151
82-POSF-0113	Stadis 450	HITEC E-515	14	153
82-POSF-0113	Stadis 450	HITEC E-515	12	146
82-POSF-0113	Stadis 450	HITEC E-515	10	146
82-POSF-0113	Stadis 450	HITEC E-515	8	164
82-POSF-0113	Stadis 450	HITEC E-515	7.5	164
83-POSF-1330 Base Fuel	Stadis 450	None	-	561
83-POSF-1330 Base Fuel	Stadis 450	None	-	575
83-POSF-1330 Base Fuel	Stadis 450	None	-	573
83-POSF-1330 Base Fuel	Stadis 450	None	-	580
83-POSF-1330 Base Fuel	Stadis 450	None	-	534
83-POSF-1330 Base Fuel	Stadis 450	None	-	573
83-POSF-1330 Base Fuel	Stadis 450	None	-	536
83-POSF-1330 Base Fuel	Stadis 450	None	-	587
83-POSF-1330 Base Fuel	Stadis 450	None	-	587
83-POSF-1330 Base Control	Stadis 450	None	-	554
83-POSF-1330 Base Control	Stadis 450	None	-	554
83-POSF-1330 Base Control	Stadis 450	None	-	543
83-POSF-1330 Base Control	Stadis 450	None	-	525
83-POSF-1330 Base Control	Stadis 450	None	-	543
83-POSF-1330 Base Control	Stadis 450	None	-	536
83-POSF-1330 Base Control	Stadis 450	None	-	543
83-POSF-1330 Base Control	Stadis 450	None	-	550
83-POSF-1330	Stadis 450	APOLLO PRI-19	8	397
83-POSF-1330	Stadis 450	LUBRIZOL 541	6	502
83-POSF-1330	Stadis 450	HITEC E-515	16	185
83-POSF-1330	Stadis 450	HITEC E-515	14	178
83-POSF-1330	Stadis 450	HITEC E-515	12	169
83-POSF-1330	Stadis 450	HITEC E-515	10	176
83-POSF-1330	Stadis 450	HITEC E-515	8	185
83-POSF-1330	Stadis 450	HITEC E-515	7.5	190

APPENDIX C (con't)

ELECTRICAL CONDUCTIVITY OF FUELS

Sample Identification	Antistatic Additive	Corrosion Inhibitor Added	Conc (lb/1000 bbl)	Average Conductivity (pS/m)
83-POSF-1329 Base Fuel	Stadis 450	None	-	548
83-POSF-1329 Base Fuel	Stadis 450	None	-	556
83-POSF-1329 Base Fuel	Stadis 450	None	-	573
83-POSF-1329 Base Fuel	Stadis 450	None	-	561
83-POSF-1329 Base Fuel	Stadis 450	None	-	548
83-POSF-1329 Base Fuel	Stadis 450	None	-	541
83-POSF-1329 Base Fuel	Stadis 450	None	-	556
83-POSF-1329 Base Fuel	Stadis 450	None	-	561
83-POSF-1329 Base Fuel	Stadis 450	None	-	570
83-POSF-1329 Base Control	Stadis 450	None	-	556
83-POSF-1329 Base Control	Stadis 450	None	-	568
83-POSF-1329 Base Control	Stadis 450	None	-	554
83-POSF-1329 Base Control	Stadis 450	None	-	548
83-POSF-1329 Base Control	Stadis 450	None	-	541
83-POSF-1329 Base Control	Stadis 450	None	-	539
83-POSF-1329 Base Control	Stadis 450	None	-	539
83-POSF-1329 Base Control	Stadis 450	None	-	541
83-POSF-1329	Stadis 450	APOLLO PRI-19	8	372
83-POSF-1329	Stadis 450	LUBRIZOL 541	6	493
83-POSF-1329	Stadis 450	HITEC E-515	16	169
83-POSF-1329	Stadis 450	HITEC E-515	14	180
83-POSF-1329	Stadis 450	HITEC E-515	12	180
83-POSF-1329	Stadis 450	HITEC E-515	10	180
83-POSF-1329	Stadis 450	HITEC E-515	8	196
83-POSF-1329	Stadis 450	HITEC E-515	7.5	200
83-POSF-1333 Base Fuel	Stadis 450	None	-	376
83-POSF-1333 Base Fuel	Stadis 450	None	-	333
83-POSF-1333 Base Fuel	Stadis 450	None	-	322
83-POSF-1333 Base Fuel	Stadis 450	None	-	322
83-POSF-1333 Base Fuel	Stadis 450	None	-	317
83-POSF-1333 Base Fuel	Stadis 450	None	-	322
83-POSF-1333 Base Fuel	Stadis 450	None	-	331
83-POSF-1333 Base Fuel	Stadis 450	None	-	344
83-POSF-1333 Base Fuel	Stadis 450	None	-	342
83-POSF-1333 Base Control	Stadis 450	None	-	356
83-POSF-1333 Base Control	Stadis 450	None	-	342
83-POSF-1333 Base Control	Stadis 450	None	-	342
83-POSF-1333 Base Control	Stadis 450	None	-	335
83-POSF-1333 Base Control	Stadis 450	None	-	335
83-POSF-1333 Base Control	Stadis 450	None	-	340
83-POSF-1333 Base Control	Stadis 450	None	-	347
83-POSF-1333 Base Control	Stadis 450	None	-	349
83-POSF-1333	Stadis 450	APOLLO PRI-19	8	262
83-POSF-1333	Stadis 450	LUBRIZOL 541	6	246
83-POSF-1333	Stadis 450	HITEC E-515	16	164
83-POSF-1333	Stadis 450	HITEC E-515	14	164
83-POSF-1333	Stadis 450	HITEC E-515	12	157
83-POSF-1333	Stadis 450	HITEC E-515	10	153
83-POSF-1333	Stadis 450	HITEC E-515	8	153
83-POSF-1333	Stadis 450	HITEC E-515	7.5	162

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